DE GRUYTER OPEN

Agriculture (Poľnohospodárstvo), 63, 2017 (3): 120−127

Original paper DOI: 10.1515/agri-2017-0012

IMPACT OF OPERATING TEMPERATURE OF GAS TRANSIT PIPELINE ON SOIL QUALITY AND PRODUCTION POTENTIAL OF CROPS

DANIELA HALMOVÁ*, ZUZANA POLÁKOVÁ, LÝDIA KONČEKOVÁ, ALEXANDER FEHÉR

Slovak University of Agriculture in Nitra, Slovak Republic

HALMOVÁ, D. – POLÁKOVÁ, Z. – KONČEKOVÁ, L. – FEHÉR, A.: Impact of operating temperature of gas transit pipeline on soil quality and production potential of crops. Agriculture (Poľnohospodárstvo), vol. *63*, 2017, no. 3, p. 120–127.

The aim of this study is to investigate the effects of gas transit pipeline temperature on soil moisture, soil temperature and yield of harvest crops. The study area was located in the village Ivanka pri Nitre (Nitra District, Southwestern Slovakia). Soil type in the site is Orthic Brown Chernozem. Temperature of the transported gas increased the soil temperature in the range of 2.07°C to 3.4°C measured in a depth ranging from 250 mm to 350 mm above the gas lines. The temperature also reduced soil moisture by 1.27–3.18 percentiles of weight. Yield of the winter wheat grown above the gas lines was higher by 9.40% in 2004 and by 13.06% in 2006. Yield of the sunflower grown above the gas lines was higher by 8.05% in 2005. In treatment 1, organic fertilisation in a dose of 50 t/ha affected the yield of the winter wheat above the gas pipeline and the yield increased by 13.95% in 2004.

Key words: gas pipeline, soil moisture, soil temperature, sunflower, wheat, yield

Agricultural land is economically important and it is an integral part of the landscape. It is the most common type of rural cultural landscape, where soil plays a primary function. Many types of landscape are exposed to many negative impacts caused by human interventions, which reduce its ecological stability (Yakovleva 2011; Olson & Doherty 2012; Shi *et al.* 2015). Therefore, it is necessary to constantly monitor and evaluate the changes of biotic and abiotic components of the landscape. The landscape is also significantly affected by transit pipelines. It has disrupted the original landscape and affected its production ability. Installing the gas pipeline into the soil caused a soil cover destruction. The soil degradation caused by pipelines was reported by Rusanova (1997) and Soon *et al.* (2000), and its effect on the soil erosion was evaluated by Bayramov *et al.* (2013) and Shi *et al.* (2014); the destruction of soil cover and significantly different soil characteristics even after 20 years was confirmed by Gel'tser *et al.* (1990). Changes in plant species composition visible after 12 years were recorded by Walker and Koen (1995) and the impact on vegetation state was reported by Xiao *et al.* (2014). In addition to the disruption of the natural arrangement of soil profile horizons and properties, the transported gas permanently affects the soil (Széplaky *et al.* 2013), plants grown on it and probably micro- and macro-edaphon due to the increased temperature. Gas temperature at the outlet of the compressor station is usually

Ing. Daniela Halmová, PhD. (*Corresponding author), Department of Sustainable Development, FESRD – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: daniela.halmova@uniag.sk
Dr. Ing. Zuzana Poláková, PhD., Department of Statistics and Operations Research, FEM – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: zuzana.polakova@uniag.sk
Ing. Lýdia Končeková, PhD., Department of Ecology, FESRD – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: lydia.koncekova@uniag.sk
Dr. Ing. Alexander Fehér, PhD., Department of Sustainable Development, FESRD – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: alexander.feher@uniag.sk

40°C. It increases the temperature of the studied soil and causes changes in its moisture conditions (Gu *et al.* 2004; Wen *et al*. 2006; Penuelas *et al*. 2007; Krakauer *et al*. 2010).

The aim of this paper is to find out how the increased temperature of the transported gas affects the soil moisture and crop yields, and investigate the impact of the intensification factor (organic fertiliser) on the yield of the crops grown above the pipelines.

MATERIAL AND METHODS

The experiment was established on an agricultural land cultivated by agricultural farm PD Ivanka pri Nitre (Nitra district, SW Slovakia), on a site located close to the transit pipeline. The site is located behind the gas compressor stations in Ivanka pri Nitre, where the soil is affected by a higher temperature of the pressurized gas. The soil type is Luvic Chernozem. The disturbance of soil cover caused by the construction of transit pipeline was found in the form of Regosol (Relocatic) deposited directly above the gas pipelines (Skalský *et al*. 2002).

The crop rotation on the monitored site was as follows: 2004 winter wheat (variety Brea), 2005 sunflower (variety Pedro) and 2006 winter wheat (variety Bonita).

Plots (1.5 m × 3.0 m) were staked above five lines of the transit pipeline in two treatments:

– Treatment 1 – soil disturbed by the pipeline construction fertilised with compost-based organic fertiliser – Vitahum (200 g of Vitahum was dried for eight hours, weight of dry mass was 80.4 g and content of nutrition was: 1.9% N, 0.5% P, 0.9% K) as a growing medium in the dose of 50 t/ha, which was used as a single application on the experimental plot during the establishment of the experiment,
– Treatment 2 – soil disturbed by the pipeline construction that was not fertilised – served as the Control treatment above the pipeline.

Individual treatments were separated by a 2 m wide strip of land.

– Treatment 3 – soil undisturbed by the pipeline construction that was not fertilised – served as the Control treatment 20 m from the gas lines.

Each treatment consisted of five plots.

The aim of the soil temperature moisture measurement was to prove the existing difference between the temperature of the soil above and outside the transit gas pipeline. Soil temperature due to fluctuation of gas temperature (in shorter time intervals)

Table 1

Average monthly and annual temperature [°C] during 2004, 2005 and 2006

Year	Month												Annual $\bar{x}$
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	
2004	–3.1	1.6	4.7	11.7	14.3	17.9	20.0	20.1	15.2	11.7	5.7	0.8	10.1
2005	–0.1	–2.6	2.7	11.0	15.2	18.0	20.7	19.1	16.3	10.7	4.2	0.4	9.6
2006	–4.1	–1.6	3.5	11.4	14.0	19.2	22.6	17.3	16.6	12.2	7.5	3.2	10.2

Table 2

Monthly and annual amount of precipitations [mm] during 2004, 2005 and 2006

Year	Month												Annual Σ
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	
2004	55.9	31.1	52.8	36.3	36.9	93.8	33.8	19.4	36.7	45.3	45.7	26.8	514.5
2005	36.4	53.0	3.4	78.7	60.9	31.5	59.0	94.5	47.1	12.1	43.2	113.2	633.0
2006	57.4	39.0	35.2	48.1	95.6	63.9	23.7	84.0	12.7	15.3	24.4	7.8	507.1

was not evaluated. Therefore, measurements were made once a month during the crop growing season. The same aim was also observed for soil moisture.

The soil temperature was measured at a depth of 0.25–0.35 m using a digital thermometer, above each line of the pipeline as well as further away from the pipeline. Subsequently, the arithmetic mean of the measured values was calculated.

The soil samples to determine the moisture content were taken at the same time as the measurements of the soil temperature, during the growth period. The soil moisture was calculated by the gravimetric method – percentage by weight (*after* Houšková 1999). Average monthly and annual temperature, and monthly and annual amount of precipitations during 2004−2006 (Šiška & Čimo 2006; Čimo 2007) are listed in the Tables 1 and 2.

Green biomass of seven winter wheat plants was collected from individual plots (35 plants per treatment) above each gas pipeline and further from the pipeline as well (comparable number of plants) in May. The fresh weight of the plants was determined after their collection. The samples were dried at 105°C to a constant weight and their dry weight was determined. The data obtained were used to compare the difference in the weight of plants grown above the pipeline and away from the pipeline. The weight of the sunflower fresh biomass was not evaluated for technical reasons.

The wheat and sunflower yields were evaluated from one square meter in three replicates from each plot, above each line of the gas pipeline and away from the pipeline. After the final grain cleaning, the grain yield was calculated and the weight of 1,000 grains was evaluated. Arithmetic means were calculated from the obtained results.

Statistical hypotheses testing method was used to process statistical differences between the treatments, since this method offers tests of contrasts through unpaired t-tests. The testing was done on significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

The average temperature of the gas at the outlet of the compressor station in Ivanka pri Nitre ranged from 24.2°C to 40.0°C in 2004, from 24.3°C to 39.0°C in 2005 and from 19.4°C to 35.4°C in 2006 (SPP Inc. 2004–2006) depending on the amount of transported gas. The highest differences in the gas temperature at the inlet and outlet of the compressor station were 25.4°C, 19.4°C and 20.5°C, respectively during 2004–2006.

Soil temperature and soil moisture

Based on the trend of average temperatures and soil moistures during 2004–2006 (Figure 1–3), we can state that the soil temperature measured above the pipelines was always higher than the temperature measured away from the pipelines. The same results were recorded by Demo and Poláková (2012) from the Veľké Kapušany (Michalovce District, SE Slovakia) and Jablonov nad Turňou (Rožňava District, SE Slovakia).

The difference was affected mainly by the temperature of the transported gas that increased the soil temperature. This fact also had an effect on the soil moisture above the pipeline. Statistically highly significant difference was observed in 2004, when the soil temperature above the pipeline was on average 3.4°C ($P = 0.0000003 < \alpha = 0.01$) higher than the soil temperature away from the pipeline and the soil moisture was on average 1.27 percentage of weight [wt %] ($P = 0.0004 < \alpha = 0.01$) lower than the soil moisture away from the pipeline. In 2005, the temperature above the pipeline was 2.07°C higher (average value) and the moisture 0.10% lower (average value) than the value measured further from the pipeline. In both cases, we did not find any statistically significant differences. In 2006, a higher soil temperature by 2.25°C above the pipeline was recorded. It represents a highly significant difference ($P = 0.00028 < \alpha = 0.01$) compared with the soil temperature away from the pipeline. At the same time, the soil moisture was on average 3.18 wt % lower as compared with the soil moisture measured away from the pipeline. The soil temperature above the gas pipeline was higher due to the exposure of the transported gas temperature than the soil temperature in the treatment located 20 m from the pipeline. A high statistically significant difference was observed in 2004 and 2006.

Except the air temperature and precipitations, the soil temperature and moisture were affected

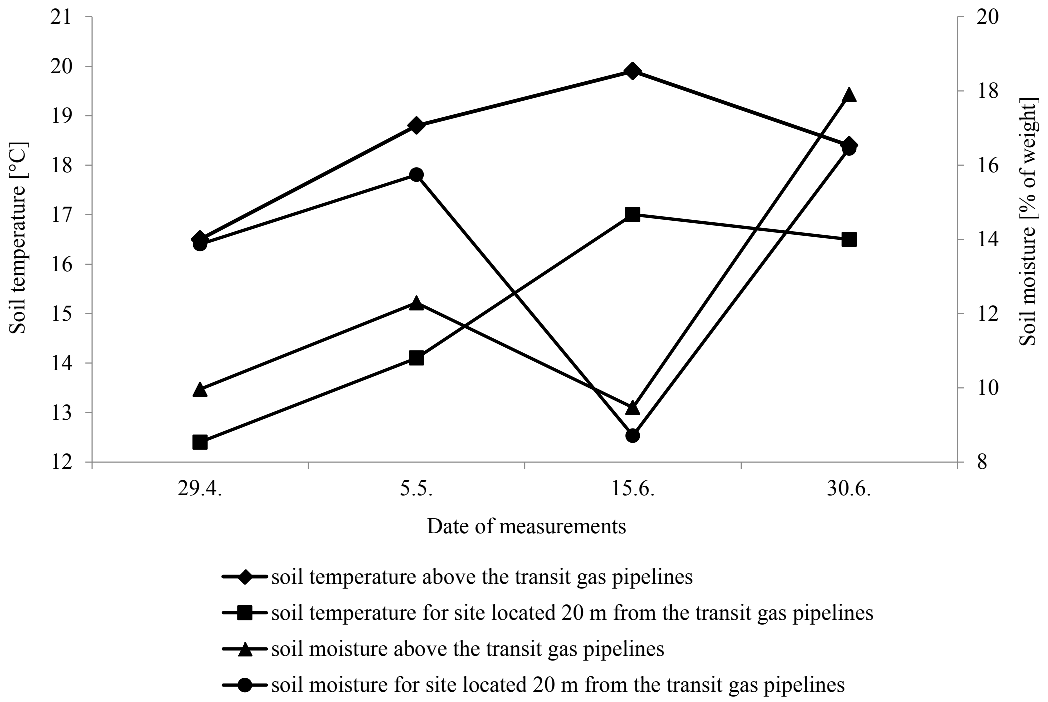

Figure 1. Trend of the average soil temperature and soil moisture, Ivanka pri Nitre during the growing period 2004

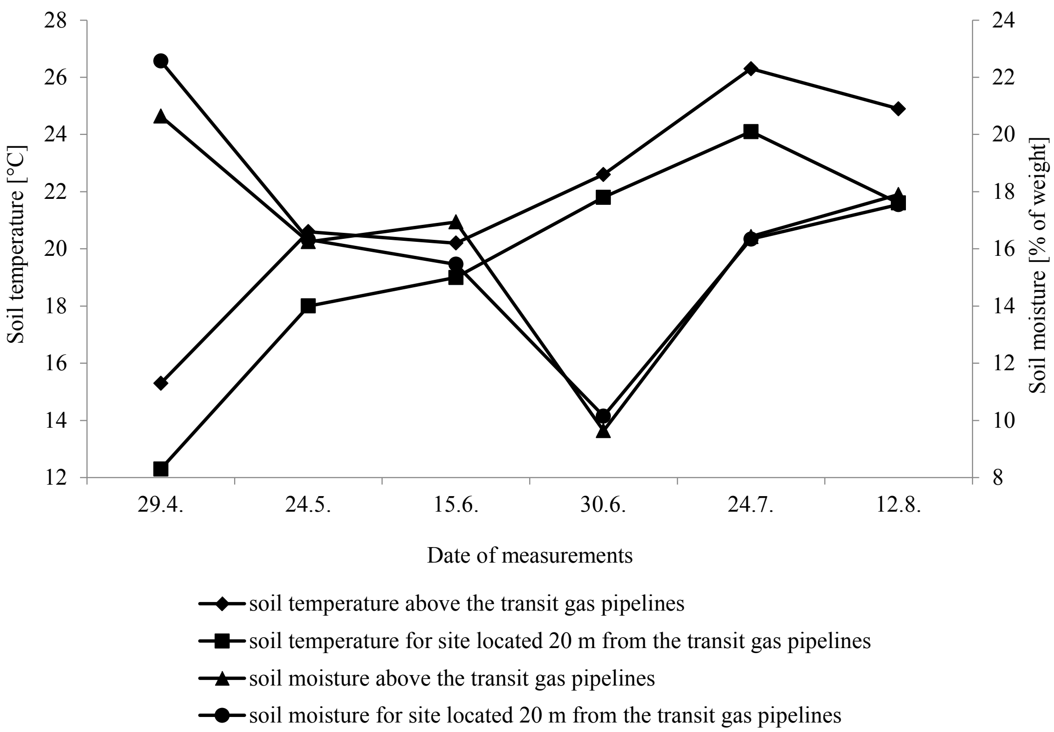

Figure 2. Trend of the average soil temperature and soil moisture, Ivanka pri Nitre during the growing period 2005

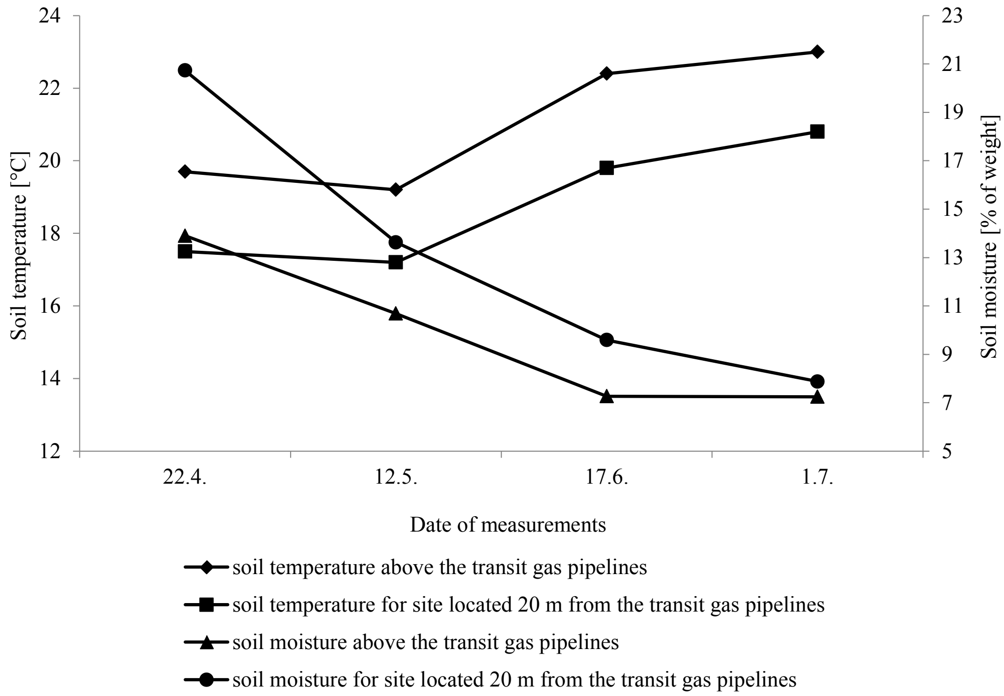

Figure 3. Trend of the average soil temperature and soil moisture, Ivanka pri Nitre during the growing period 2006

also by the temperature of the transported gas – the increased soil temperature above the pipeline led to the reduction of its moisture. A high statistically significant difference was observed in 2004.

Impact on a phytomass and yield

The higher soil temperature caused by the temperature of the transported gas, together with sufficient sources of winter moisture and nutrients, significantly influenced not only the growth and development of the crops grown directly above the pipelines, but also in the adjacent land strips. The difference in the plant heights obtained above the pipeline was visible in the early stages of the growth and lasted until the harvest. Similarly, the differences in the height of sunflower (in the beginning of flowering) ranged from 0.25 to 0.30 m and persisted until the harvest.

The height differences in the winter wheat ranged from 0.25 m to 0.30 m in April 2004 and from 0.1 m to 0.2 m in May 2006, and partially decreased until the harvest of the plants (the differences were up to 0.1 m). Evaluation of the above-ground wheat biomass provided the following results. In absolute terms, the weight of the dry matter was in both studied years higher by 33.12% (2004) and 18.12% (2006) on the soil above the pipeline. Effect of the organic fertiliser was only in the first studied year when the biomass weight was 48.93% (2004) higher compared with the control treatment 3.

Winter wheat grew faster on the soil above the pipeline. Individual growth phases, such as flowering and maturation began 10–14 days earlier as compared with the wheat growing further from the pipeline. Organic fertilisation, in the treatment 1, had no significant effect on the ears/head density of the winter wheat and sunflower stands. The number of wheat spikes per m^2 was the highest on the soil undamaged by the pipeline construction (Figure 4). However, this fact did not affect the crop yields (the weight of 1,000 grains was the lowest, Halmová, (2009)). The number of sunflower flower heads per m^2 was in all three

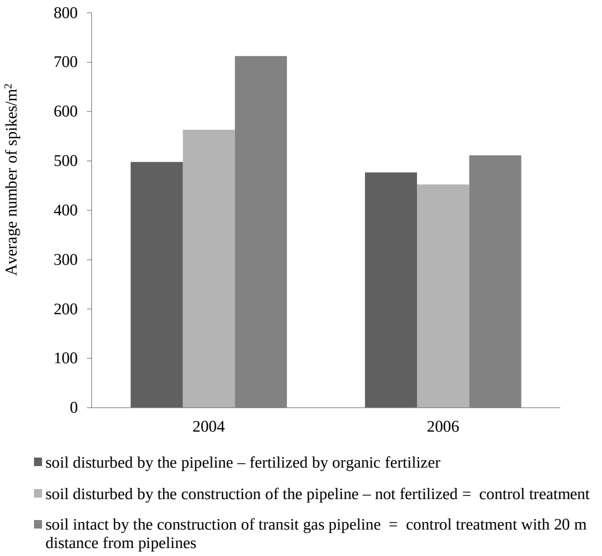

Figure 4. Average number of winter wheat spikes per m^2, Ivanka pri Nitre, 2004 and 2006

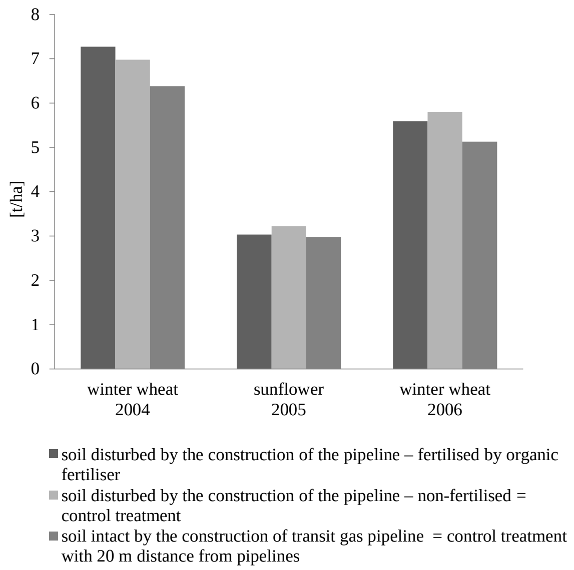

Figure 5. Crop yields trend, Ivanka pri Nitre 2004–2006

treatments comparable and ranged from 5 to 5.27 (in 2005).

The grain yields of wheat (Figure 5) were higher by 9.4% (2004) and 13.6 % (2006) on the soil disturbed and affected by the pipeline compared with the yields obtained on the soil unaffected by the pipeline. Blaško (2005) found lower wheat yields on the Cambisol in extremely dry years 2002 and 2003. The same results were recorded by Demo *et al.* (2012) from the Cabaj-Čápor (Nitra District, SW Slovakia) site that is also located behind the gas compressor station Ivanka pri Nitre.

Similarly, the sunflower yields were 8.05% higher on the soil affected by the pipeline compared with the control treatment. This corresponds to the findings of Blaško (2005).

The impact of the fertilisation was observed only in the winter wheat yields in the first experimental year.

Rainfall and its distribution during the growing period was an important factor affecting the crop yields. Taking into consideration that the constant impact of the transported gas temperature affects the temperature and moisture regime of the concerned soil, it can be assumed that the crop yields were reduced during the years with low precipitation. Another important factor influencing the crop yields except the soil type might be the persistence of soil damage caused by the pipeline construction (Halmová & Fehér 2014). Chemical properties of the soil were evaluated during the three-year research, as well. Only minimal differences in the values of the basic pedo-chemical parameters of the damaged and undamaged soils were recorded (Halmová 2009).

An increase in the yields of the crops (wheat and sunflower) grown on the soil above the pipeline was recorded in each of the studied years. It is assumed that the yield increase occurred mainly due to the combination of the three factors: the soil type, uniform distribution of rainfall (cf. Šiška & Čimo 2006; Čimo 2007) during the growing season and increased soil temperature caused by the transported gas.

CONCLUSIONS

The gas transit pipelines affect some soil characteristics as well as crop yields. These changes do not necessarily repeat regularly but depend on weather conditions, amount of transported gas and crop grown in the given year. These soils are usually drier and warmer than soils that are not affected by temperature of the transported gas.

Amount and distribution of precipitations during the growing period is a very important factor. Crop yields on the soils above the pipelines can be expected to be higher; however, they are endangered by faster crop maturation and the resulting losses. The gas transit pipeline is a linear structure with an indisputable importance for the economy, impacts caused by its construction and operation can still be seen today.

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Received: June 30, 2017